ZWICKER'S

PRACTICAL INSTRUCTOR

FOR

MACHINISTS, FIREMEN

AND

STEAM ENGINEERS.

ZWICKER'S

INSTRUCTOR,

—THE—

ONLY PRACTICAL WORK PUBLISHED,

—FOR—

MACHINISTS, FIREMEN

—AND—

Steam Engineers.

BY PHILIP HENRY ZWICKER,

PRACTICAL ENGINEER AND MACHINIST.

ST. LOUIS, MO.
1888.
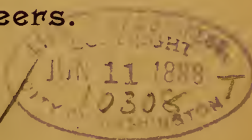
PREFACE.

In the following pages I have explained the practical points of the Steam Boiler, Engine, Pump, Indicator, Safety Valve, U. S. Standard Rules and the gearing of a lathe to cut any size and kind of thread, in a clear and concise manner, so as to be easily understood by men whose education is limited.

I have also appended important tables so simple that they can be readily understood. Almost all calculations connected with the use of steam can be calculated, providing the first four rules of the arithmetic are known viz : Addition, multiplication, subtraction and division. These hints and examples are intended to show how many practical improvements can be made by engineers, firemen and machinists.

The importance of this book is, to keep engineers informed of their duty in regard to the safety valve, engine, boiler, pump and

indicator. An engineer of plain education, studying this book, will find that it is simple and easily learned; also the only book published explaining these things clearly and to the point.

Every engineer, fireman and machinist ought to know perfectly well, without the necessity of any elaborate calculations, theorizing, or calling in the services of some expert (engineer) to tell him clearly what would occur if he should overload his engine, boiler or any machinery under his charge.

I trust this book will be of service to those who intend to follow steam engineering, as well as to all whose business make it necessary to use steam.

PHILIP H. ZWICKER,

AUTHOR.

ZWICKER'S

INSTRUCTIONS

— IN —

QUESTIONS AND ANSWERS

— FOR —

Machinists, Firemen and Steam Engineers.

QUESTION.   Are you a machinist?

ANSWER.   Yes or no.

Q.   Have you worked at finishing?

A.   Yes or no.

Q.   What kind of boilers are there?

A.   There are different kinds; such as flue, tubular, hanging-fire box, upright and various other kinds, but the above named are most in use.

Q.   Of what is a boiler composed and made?

A.   A steam boiler is made out of steel or iron plates, the most in use is $\frac{3}{8}$, $\frac{1}{2}$ and $\frac{5}{16}$ inch

thick, and ranging from 45,000 to 85,000 lbs. tensile strength; these plates are run through a rolling machine and rolled in a circle, then riveted together, generally with two rows of rivets, because the strain is greater sidewise than endwise, the seams around the boiler are single rivited because the strain is not so great; the boiler is braced by different kinds of braces, such as crow foot, longitudinal, dome, side braces, etc. The eye is riveted to the head of the boiler, which head is generally made of $\frac{5}{8}$ inch plate, the other eye is riveted to the side, top or dome of boiler; and the brace and eye are put together by bolts with a split key to keep the bolt in place.

Q. How should a brace fit?

A. It should fit tight, for if it were loose it would be of no account.

Q. If you found a brace loose, what would you do and how would you tighten it?

A. By taking the brace out, heat it in the center, then upset it by jumping it end-wise on a block of wood until it is the proper length.

Q. Why is a boiler braced?

A.   For strength.

Q.   What is a stay-bolt?

A.   A stay-bolt is a screw bolt, put through an outside and into an inside sheet, so as to hold them that they may not spread or collapse, such as a fire-box sheet and an outside shell, they are put together with stay-bolts so as to allow a water space between the two sheets.

Q.   How is a stay-bolt made and put in?

A.   They are made with one continuous thread, and screwed through the outside, then through the space between, then through the fire-box sheet and allowed to stick through $\frac{3}{16}$ of an inch, so they can be riveted over each end to act as a brace, the space between the two sheets is called a water space.

Q.   What is meant by corrosion?

A.   It means wasting away of the iron of boiler plates by pitting, grooving, etc. There is internal and external corrosion; the acids and minerals in the water liberated by the heat, attack the boiler internally, and the sulphur which comes out of the coal has a

strong attachment for the iron, and that attacks the outside.

Q. How would you find the water level when your boiler is foaming?

A. The proper way would be to shut down the engine and all valves connected with the boiler, cover fire with ashes, close the damper, then the water will quiet down, and the level of the water easily found. An engineer should know when lighting a fresh fire, never to force it, but let it heat gradually, so that all parts expand as near equal as possible; good judgment is needed. Boilers and steam gauges should be tested at least once a year.

Q. Where would you put a steam gauge?

A. Sometimes on top of the boiler, and in some cases on the steam drum. It must always be tapped into the steam part of the boiler, the shorter the pipe the better. The steam gauge and safety valve should correspond.

Q. Why is a pet cock put under the steam gauge?

A. To drain the pipe in cold weather.

Q.   What kind of a steam gauge have you got?

A.   A spring gauge.

Q.   What is a steam gauge for?

A.   To indicate the pressure in pounds per square inch in the boiler.

Q.   Does the steam gauge get out of order?

A.   Yes.

Q.   If the steam gauge was out of order what would you be governed by?

A.   By the safety valve.

Q.   How would you know that it was in order?

A.   By raising the lever two or three times to see that the valve is not stuck.

Q.   What is a safety valve for?

A.   It is intended to release the boiler and prevent explosions from over-pressure.

Q.   How large should the safety valve be in proportion to the boiler, and grate surface?

A.   The safety valve should be $\frac{1}{2}$ square inch to each square foot of grate surface, which will make it large enough to relieve the boiler of all steam generated over which the safety valve is set.

Q. What is the best, gauge cocks or glass gauges, and what would you be governed by?

A. Gauge cocks, because glass gauges are liable to get stopped with mud, and not give a true level of the water, but they are a very handy thing; they should be blown out four or five times a day, so as to keep them free from clogging up.

Q. What would you do in case a glass should happen to break?

A. First close the water valve to prevent the escape of water, close the steam valve, insert a new glass, then turn on the steam valve first, the water valve next, then close the pet cock at the bottom and everything will be all right.

Q. What is the best way to clean a glass gauge inside?

A. The best way, is to take a small piece of waste and tie it to a strong thin stick, saturate the waste with soap or acetic acid, pass down inside of the glass, then blow through with steam and the glass will be clean as new. Never touch the inside of a glass water gauge with wire, if you do, it will

crack. The best glasses are the Scotch brand, called Eureka.

Q. If your gauge cock, or a small pipe in the large steam pipe, should happen to get broken off, what would you do?

A. Make a hard-wood plug and drive it in with a heavy hammer, then leave it so until it could be repaired, by cutting out the old piece, retapping and putting in another pipe or gauge cock, whichever the case may be.

Q. What clearance should a boiler have?

A. It should have from 3 to 4 inches at the fire line, and from 5 to 7 inches between the shell and bridge wall; a boiler should have from 2 to 3 bridge walls so the fire will hug the boiler; it also makes the coal burn cleaner and steams easier. The first bridge wall should be on the back end of the grate bars, and the others about 3 to 5 feet apart, according to the length of the boiler. Where the smoke returns through the flues, it should be about ⅓ larger than the area of flues or tubes combined, bridge walls should lean toward the back.

Q.   How should a boiler rest and what on ?

A.   The front end of the boiler should rest on the fire front, and the back end generally rests on a cast iron leg or two rollers, to allow the boiler to expand equally.   The mud drum should always hang free under all circumstances.   Engineers should be careful in starting or stopping an engine with a high pressure of steam, because the rent in giving the steam in starting, and the sudden check in stopping, may cause such a pressure as to rupture the boiler.   Engineers should see that their draft is not choked by ashes under the boiler, and that the outside of the boiler and inside of flues are kept clean, then they will have no trouble in keeping up steam.

Q.   In case the throttle valve snould become loose from the stem and prevent the steam from entering the valve chest, what would you do ?

A.   Close the valve next to the boiler, if there was one ; if not, let the boiler cool down, then take the valve out and repair it.

Q.   What different strains has a boiler ?

A. To the flues or tubes it has a crush. ing strain, to the shell a tearing strain.

Q. What causes boiler explosions ?

A. There are various causes, such as low water, over-pressure of steam, bad safety valve, foaming boilers and burnt sheets.

Q. Why would a foaming boiler cause an explosion ?

A. It generally raises the water from the heated sheets. They become hot ; the water falling back on them they crack, and some-times cause an explosion. A blistered sheet or a scaly boiler will also cause an explosion, by allowing the sheets to became burnt and weakened ; also, an untrue steam gauge is very bad.

Q. What are the worst explosions ?

A. The worst explosions are caused by high pressure and plenty of water ; low water allows the iron to burn and crack, which weakens it, and when the cold water touches it, it does not take so much to burst.

Q. How would you know if your boiler had blistered sheets or was rotten ?

A. By the hammer test ; by taking a

small hammer and going inside and outside of the boiler and seeing if it is all right by sounding it.

Q.   How would you know by sound?

A.   By the different sounds it has; if it rings and sounds solid it is all right; but if it sounds dead, hollow or blunt, there is something wrong.

Q.   Would you strike the iron hard?

A.   Yes, pretty hard.

Do not hesitate to have a boiler insured, as insurance is generally accompanied by hammer test and intelligent inspection, which guarantees safety to the engineer, owner or steam user.

Do not reject the advice or suggestions of intelligent boiler inspectors, as their experience enables them to discriminate in cases which never come under the observation of men who do not follow inspection as a business.

Q.   If you wished to put a patch on a boiler, what kind would you put on?

A.   A hard patch; it is reliable and safe.

Q.   Why not put on a soft patch?

A.   Because they are not reliable and are dangerous.

Q.   What is the difference between a hard and soft patch?

A.   A hard patch is a patch where the piece is cut out of the boiler and rivet holes are drilled or punched through, then the patch is riveted on, chipped, corked and made water and steam tight.

Q.   What is a soft patch?

A.   A soft patch is put over the plate that needs patching, and put on with $\frac{5}{8}$ or $\frac{3}{4}$ inch countersunk screw bolts, and a mixture of red lead and iron borings to put between the patch and boiler; the piece of sheet in the boiler is not cut out for a soft patch as in a hard patch, consequently the patch is burnt, as the water in the boiler can not come in contact with the patch.

Q.   What is the best, drilled or punched holes?

A.   Drilled holes are the best?

Q.   Why?

A.   Because the fiber of the iron is not disturbed as in punching; in drilling, the

iron is cut out regular ; in punching, it is forced out at once.

Q. What should be the proper rivets for certain sized sheets, and how far apart ?

A. The rivets should be $\frac{5}{8}$ and $\frac{3}{4}$ inch diameter, and $1\frac{1}{2}$ to $1\frac{3}{4}$ inches apart.

Q. Before shutting down at night, what would you do ?

A. Pull out the fire, pump up to the third gauge and close the glass gauge cocks, so that in case the glass should happen to get broken during the night, the water could not escape.

Q. What would you do the first thing in the morning on entering the fire-room ?

A. See how much water was in the boiler by trying the gauge cocks, open the glass gauge valves, and start the fire to raise steam.

Q. Why do you try the gauge cocks, and not trust to the glass gauge ?

A. Because the water pipe connecting the glass gauge with the boiler is liable to become stopped up with mud, consequently the glass would not show a true level of water. The

glass gauge should be blown out five or six times a day, to insure safety, but never depend on the glass alone.

Q. If you found too much water in the boiler during the day, what would you do?

A. Open the blow-off valve and let out water to the second gauge. An engineer should be very careful when blowing out water when he has a hot fire in the boiler furnace, as the water leaves very fast, and may blow out too much ; good judgment should be used.

Q. How would you clean the flues or tubes of a boiler?

A. By either blowing steam through them or using a flue-cleaning brush.

Q. How are flues or tubes cleaned with steam?

A. Some boilers have an $1\frac{1}{2}$ inch pipe with a valve attached, also branch pipes of smaller dimensions, leading from the $1\frac{1}{2}$ inch into the back end and into the flues ; others have a hose attached to the front end leading from the steam drum, so flues or tubes can be blown out from front end. (CLEANING BY BRUSH IS BEST.)

Q. How often would you clean out the flues, and when?

A. Once a day, and in the afternoon. Sometimes in the morning after raising steam.

Q. How would you clean a boiler?

A. First see that no fire is under the boiler, then let out all the water through the blow-off valve, take out the man, hand, and mud-drum plates; then take a short-handle broom, a candle or torch, a small hand-pick, a scraper made out of an old file flattened on the end and bent to suit, also a half-inch square iron twisted link chain, about 3 feet long, with a ring at each end to answer for a handle; place chain around the flue and work the chain to get the scale off the bottom of the flues; use the pick and scraper to pick and scrape off all that can be seen on top of flues and the bottom and sides of shell; then wash out into the mud-drum; clean out and put in the mud-drum and hand-hole plates; fill up to top of flues; then put in man-hole plate, and fill up to second gauge ready for raising steam.

Q. Could a boiler not be blown out?

A.   Yes.

Q.   How much pressure would you allow?

A.   About 10 or 20 pounds.

Q.   Why not more pressure?

A.   Because the heat would be so great that the expansion and contraction would not be equal; consequently, the boiler seams would probably leak and the boiler be injured.

Q.   What benefit is gained by letting water stay in the boiler until you are ready to clean out?

A.   The mud is kept soft and the scale is not caked to the bottom; also, the seams and boiler are not injured by unequal expansion and contraction.

Q.   How should a man and hand-hole plate be taken out and put in?

A.   They should be marked with a chisel at the top, also the boiler at man-hole and hand-hole, whichever it might be, and they should be put in the same way they came out.

Q.   How would you gasket man-hole or hand-hole plates?

A.   With pure lead rings ; some use sheet rubber.

Q.   Why are man-hole and hand-hole plates made oblong instead of round ?

A.   Because if they were round they could not be taken out, and a man could not easily enter the boiler.

Q.   When filling a boiler with cold water and raising steam, what should be done ?

A.   A valve should be left open.

Q.   Why ?

A.   Because a boiler fills easier and quicker, and in raising steam the cold air is let out, which allows equal expansion, as cold air prevents equal expansion.

Q.   How would you set a boiler ?

A. - By using a spirit level across and along the flues, allowing the end furthest from the gauge cocks $\frac{1}{4}$ inch lower for every 10 feet in length.

Q.   Why ?

A.   Because when there is water in the gauge cocks, there will surely be water in the other end.

Q.   How many gauge cocks has a boiler ?

A.   Generally three.

Q.   Where is the first?

A.   Two inches above the flues, and the rest two inches apart.

Q.   Where is the water line?

A.   First gauge.

Q.   Where would you carry water when running?

A.   Second gauge.

Q   Where would you carry water when shutting down at night?

A.   Third gauge.

Q.   Why?

A.   To allow for evaporation, leakage and condensation.

Q.   Where is the fire line of a boiler?

A.   In line or little below first gauge.

Q.   When you open a boiler and look in, where do the scales form and lay thickest?

A.   Over the fire-plates and around the mud-drum leg or blow-off pipe.

Q.   Why?

A.   Because the circulation and heat is greatest there.

Q.   What is a steam drum for?

A. To have more volume and dryer steam.

Q. Which is the hottest, steam or water?

A. They are the same, only water will retain the heat longer, as water is a body and steam a vapor.

Q. How should the circulation and feed be?

A. The circulation and feed should be continual.

Q. Why?

A. Because boilers have exploded just as the steam valve was opened to start the engine, after having stood still for some time. This is generally caused by the plates that are in contact with the fire becoming overheated, as the circulation being stopped after the steam is shut off. And just as soon as the valve is opened the pressure becomes lessened, and the water on the overheated sheets flashes into steam of GREAT ELASTIC FORCE, and if the boiler is not strong enough, a terrific explosion is the result.

Q. If you tried the gauge cocks and found no water in sight, what would you do?

A. Simply put wet ashes over the fire and pull it out, raise flue caps and let the boiler cool down.

Q. Why do you throw wet ashes over the fire before pulling it out?

A. If the fire was stirred up it would create more heat and be liable to burn the plates.

The braces in the boiler should be examined to see if they are loose, also the sheets, flues, heads and seams, to see if they are cracked or leaking; if they are not attended to, they may cause trouble and loss of life and limb. Engineers should not allow anything about the engine or boiler room to become greasy or dirty, for it shows poor management, and a careless, worthless engineer. If valves or cocks leak, they should be ground in with emery and oil until a seat or true bearing is found.

Q. When should the boiler seams be corked?

A. When the boiler is empty and cold, for when the boiler is hot and filled with water, the jarring while corking would have a tendency to spring a leak somewhere else.

Q. Would you call pressure and weight the same?

A. No.

Q. Why?

A. Because pressure forces in every direction, while weight presses down.

Q. Which is best, riveted or lap-welded flues?

A. Lap-welded flues, as they are a true circle and not so easily collapsed as riveted flues.

Q. Why?

A. Because the riveted flues are not a true circle.

Q. What is foaming?

A. Foaming is water and steam mixed together.

Q. What causes foaming?

A. Dirty, greasy, oily and soapy water; salt water forced into fresh water, also too much water and not enough steam room, will cause foaming.

Q. What is priming?

A. Priming is the lifting of water with steam, such as opening a valve suddenly, and

drawing water from the boiler to the cylinder of the engine.

Q. What would you do in that case?

A. Close the throttle valve and leave it closed for a few minutes, then open slowly; that will remedy it. Sometimes priming is caused by too much water and not enough steam room; in this case carry a little less water.

A. Are boilers sometimes injured by hydraulic test?

A. Yes, if tested by an inexperienced person. Hydraulic test is the safest, because if the boiler is bursted no one is likely to get hurt.

Q. If you had a high pressure of steam, and water was out of sight, would you raise the safety valve to let off the pressure?

A. No.

Q. Why?

A. Because it would cause the water to rise, and when the valve closed the water would drop on the heated parts and be liable to cause an explosion.

Q. If your boiler was too small to keep

up the amount of steam required, would you weight down the safety valve to carry a higher pressure ?

A.   No.

Q.   Why ?

A.   Because that would show carelessness and a violation of the laws.   There is no mystery about boiler explosions.   They are simply caused by carelessness, and no man has the right to endanger the lives and property of others when he knows that he is incompetent to perform the duty required of him as engineer, whether licensed or otherwise.

HOW TO AVOID AND REMOVE SCALE FROM STEAM BOILERS.

To counteract the impurities of water used in steam boilers, and to clean off the scale after it has formed, are two things upon which more thought and time has been bestowed and money expended, with little or no result, than anything else connected with the use of steam ; in fact, to this very day, each engineer has his own crude way of getting at this difficulty, merely experimenting, hoping to find a remedy to overcome the evil.

In our investigation of the many different articles sold for the removal and prevention of boiler scales, we have sent out very many letters of inquiry, and reports show that we have but one article now on the market which proves itself in every way reliable ; this article is manufactured in Philadelphia, Pa., and is known as Lord's Boiler Compound. All our reports show that this article is

unanimously endorsed by professional men throughout this continent, among whom are practical chemists, authors of mechanical books, engineers in charge of works, professional inspectors and men having large capital invested in steam boilers.

The chemists for the U. S. Mint in Philadelphia, Pa., testify under oath that Lord's Compound will not injure the iron, while other reports, also of the highest authority, show that where boilers were eaten up in a year or two by acids or corrosive matter in waters, no sign of injury has been found since Lord's Compound was first applied, in 1876.

PUMPS.

Q. What kinds of pumps are there?

A. There are many kinds, but we consider only single action and double action for feeding boilers.

Q. How many valves has a single action plunger pump?

A. Two valves, a receiving and a discharge.

Q. How many valves has a double action?

A. Four, two receiving and two discharging. The double action receives and discharges both ways. This kind of pump has a steam cylinder on one end.

Q. How would you set up and level a pump?

A. Set the pump so the receiving is from the boiler and the discharge towards the boiler, put in the same size receiving and discharge pipe as tapped in the pump, so the pump can have a good supply and discharge.

The pump is leveled with a spirit level or a square and plumb line. To level a double action pump, some level across the frame and along the piston; the other way is to take the valve chamber cap off the water cylinder and level the valve seats, so the valves will rise and drop plumb. To level a single action pump, take off the valve chamber caps and level both ways.

Q. How is the water piston packed and with what?

A. It is generally packed with square canvas and rubber mixed packing; it generally takes two pieces; one piece is jointed on top, and the other on the bottom, to make what engineers call a broken joint. The packing runs from $\frac{1}{4}$ to $\frac{5}{8}$ inch square. These are the general sizes used for common sized pumps.

Q. What other valve has a pump near the boiler?

A. A check valve.

Q. What is a check valve for?

A. To check the water in the boiler from coming back, in case there is any work to be done on the pump.

Q. Could you pump water into the boiler if you had four or five check valves on the discharge pipe?

A. Yes, I could force through all, but it would be more labor on the pump, because the plunger would have to force harder to raise the number of check valves.

Q. Where is a pet cock put on pump barrel, and what for?

A. It is put at the side and near the bottom of the pump barrel, and is there to show how the pump is working, and to drain pump in winter to prevent freezing.

Q. How do you know when your pump is in good working order?

A. By opening the pet cock and seeing the stream that comes out.

Q. How does it show when in good working order?

A. Nothing on the up-stroke and full force on the down-stroke.

Q. Where would you locate the trouble if it came full force both strokes?

A. I would locate it at check and discharge valves, both being caught up?

Q. Where would you locate the trouble if it came full force both strokes, moderate, tank or hydrant pressure?

A. At the receiving valve.

Q. Can you run a pump witnout a check valve?

A. If the discharge valve is in good order, yes; but if there is neither check nor discharge, no.

Q. Can you feed a boiler without a pump at all?

A. If the pressure of boiler is below the pressure of the feed water or city pressure, I can, by simply opening a water valve and letting in the amount of water required.

Q. What other way is a boiler fed?

A. By an injector or an inspirator.

Q. Must a pump have a valve?

A. Yes, if a pump had no valve it would not do any work.

A pump is not a pump unless it has a valve. There are common well hand pumps with one valve, called a receiving or suction valve, but a force pump has two valves, a receiving and discharge; the discharge is to

retain the water after it is delivered, so the plunger can get a fresh supply. After the plunger has ascended and begins to descend, the water sets on top of the receiving and under the discharge ; consequently, when the plunger descends it forces the receiving shut and the discharge open.

Q. Should there not be another valve near the boiler ?

A. Yes, a globe valve between the check valve and boiler.

Q. What is that for ?

A. To close and keep pressure in the boiler in case the check valve is caught up and needs repairing.

Q. Can you raise, lift or suck hot water with a pump ?

A. Not very well.

Q. Why ?

A. Because the pump would get steam bound. Hot water should be level or higher than the pump in order to work well.

Q. Where should a pet cock be put on the pump barrel for hot water ?

A.   At the top of barrel, immediately under the packing ring.

Q.   Why is it put there?

A.   To let out steam when steam bound, and air when air bound.   There should be a pet cock tapped in the cap of the valve chamber to let off steam or air when steam or air bound.

Q.   If you had no pet cock on the valve chamber cap, what would you do?

A.   I would take a wrench and loosen one of the nuts a little until the air or steam was out, then tighten again.

Q.   Why is an air chamber put on a double action pump?

A.   It is simply a copper vessel air tight. When the pump is working, the water is forced up into the chamber, compresses the air, and the air acts as a cushion on the valves and piston head in the water cylinder.

Q.   What is a cushion?

A.   A cushion is anything that is compressed, and by its compression is formed into a higher and stronger pressure, consequently acting as a spring, deadening any knock that

might have occurred otherwise, as water will cause a knock, it being nearly as solid as iron, so if a double action pump had no air chamber, there would be a continual thumping noise.

Q.   What is a vacuum?

A.   A vacuum is a space void of matter.

Q.   Can a perfect vacuum be formed?

A.   No, about 9 to 11 per cent. of the atmosphere, which is 14.7 pounds per square inch.

Q.   What will a vacuum do?

A.   It will lift water 33 feet, providing all pipes and connections are air tight.

Q.   How is a vacuum created or made?

A.   When the plunger of a pump is well packed and it lifts, it excludes the air out of the pump barrel and suction pipe, consequently the water, being at the other end of the pipe, it follows the plunger; or, in other words, the atmospheric pressure, being 14.7 pounds per square inch, forces the water up the pipe to fill the vacancy made by plunger forming the vacuum.

Q. What should be placed at the bottom of the suction pipe?

A. A strainer made out of gauze wire, a foot valve and a pet cock to drain it.

Q. If your pump should not be working, your water running low, and you were asked to run a little while longer, would you run and let your water become dangerously low?

A. No, take no chances whatever, but shut down and go about repairing the trouble;

Q. Where would you look for the trouble?

A. Open the pet cock of the pump, and that will very nearly tell where to look for it; if no water comes out, the water is shut off, or there is none, etc.

Q. What generally prevents a pump from working?

A. Not enough water, too small a suction pipe and obstructions of the valves to seat, by straws, sticks or anything that may be drawn through the suction pipe, or the pump valves becoming hot and sticking.

Q. If an accident happened, such as a broken pipe connected with the boiler and

pump, or you could not get sufficient water to supply the boiler, what would you do?

A.   Simply shut down the engine and all valves connected with the boiler, draw fire, raise flue caps, and close the damper, so as to keep water in the boiler until the difficulty is repaired.

Q.   If your suction pipe should spring a leak, what would you do?

A.   Take a piece of sheet rubber, some copper wire, wrap around tight, and stop the leak temporarily.

Q.   If your hydrant, that supplies pump with water, should happen to get broken, what would you do?

A.   First see how much water was in the boiler, by trying gauge-cocks, then shut off the water in the street, or wherever the lazy cock lay, and try to wrap it, if possible, or repair it. If an injector or inspirator was attached, and was supplied from a tank or well, use them.

Q.   What is an injector or inspirator?

A.   They are a device to answer for a

pump in feeding a boiler; they draw, force and heat the water at the same time.

Q. For instance, if you had neither of these, what would you do?

A. Shut down the engine, close the damper, raise the flue caps and draw fire, whichever suited the circumstances.

Q. If your pump was turned around, could you feed the boiler?

A. No.

Q. What would be the consequence?

A. If the packing in the pump held out, the plunger would exclude the air and collapse the discharge pipe.

Q. Would it not have a tendency to drain the water out of the boiler?

A. No, the check valve near the boiler would keep it back.

Q. If you had no check valve, what would it do?

A. The water would run out, that is, providing the pump was turned around.

Q. If the pump plunger is one-half the stroke of the engine, what should the diameter be?

A.   One-third the diameter of engine cylinder.

Q.   How high should a valve lift to clear itself?

A.   About one-fourth of its diameter or one-third of its area.

Q.   What proportions should the valves be to any sized pump?

A.   They should be one-fourth the area of the pump.

THE ENGINE.

Q. What is a steam engine?

A. A steam engine is a machine by which power is obtained from steam.

Q. What is steam?

A. Steam is a gaseous vapor from water, generated from heat, composed of hydrogen and oxygen.

Q. How do you know it is hydrogen and oxygen?

A. Science shows that 1 pound of hydrogen with 8 pounds of oxygen is equal to 9 pounds of water.

Q. What is an engine composed of?

A. A bed plate, cylinder, connecting rod, crank, crank-shaft, main pillow block, tail pillow block, cross-head, wrist-pin in cross-head, crank-pin, two cylinder-heads, piston-rod, piston-head, follower head, bull-ring, packing-rings, follower plate and bolts, connecting rod and brasses, pillow-block brasses, a valve, and guides where the cross-head

slides in, so the piston is kept central with the cylinder. The main pillow-block brasses are generally made into four pieces, called top, bottom and two quarter brasses each side of shaft ; they are made into four parts, so as to take up lost motion.

Q. What keeps the rod from running off the crank pin ?

A. The shoulders on the crank-pin.

Q. Why are the stub ends of straps made heavier where the gib and key passes through ?

A. To make up for the amount of iron taken out for gib and key-way.

Q. If water should accumulate in the cylinder, what would be the consequence ?

A. It is liable to crack the cylinder and disable the engine.

Q. If you had charge of an engine in the country, and the cylinder head should happen to break, how would you remedy it ?

A. If not broken too bad, try to patch it with pieces of iron or boards, and brace it from the wall with a piece of heavy scantling, then try and run until a new cylinder head could be made.

Q. What size should a steam pipe and an exhaust pipe be to any size cylinder?

A. The steam pipe should be one-fourth and the exhaust one-third the diameter of the cylinder.

Q. If your crank pin or other journals get hot, what would you do?

A. Try, while running, to get water on them, then oil them; if that would not do, stop and slack up the key a little, then start up again.

All engine cylinders should be well drained and heated before starting, then the engine should be started slowly, as the water that accumulates in the cylinder may injure the piston, cylinder, or cylinder heads. Always leave the cylinder cocks open when not running, and they should remain so until the cylinder is heated by the steam—after the engine has been running at full speed two or three minutes.

Q. If the cylinder had shoulders inside, and was out of a true circle, what would you do?

A. Bore it, or have it bored out.

Q. If your slide-valve was not steam-tight, what would you do?

A. Have the valve planed, then chip, file and scrape the seat to a full bearing.

Q. If the crank and wrist-pins are worn out of true, what would you do?

A. Caliper and file them until they were round and true.

Q. What causes the wrist-pin in the cross-head and crank-pin to wear the way they do?

A. It is simply the motion they have; the crank goes all the way around and the wrist only vibrates.

Q. If the cross-head or crank-pin brasses were brass-bound, what should be done?

A. They should be chipped and filed.

Q. How do you know when you have taken enough off?

A. By inside and outside calipers.

Q. How does steam enter the cylinder?

A. In common slide-valve engines, it enters through one of the end ports and exhausts back through the same port, when the cavity of the valve has covered it and the exhaust port at the same time.

Q. What is a cavity?

A. It is a hollow space in the valve itself, where the exhaust passes through to the atmosphere.

On Corliss engines and other makes, there are separate valves, called exhaust valves; a Corliss has two steam and two exhaust valves.

Q. Where are they?

A. The two steam valves are on top, at each end of the cylinder, and the exhausts are at the two bottom ends.

Q. What are the advantages of common slide-valve engines over other makes?

A. They are cheaper when first bought, more positive in their action, and simpler in design; still, they are very wasteful.

Q. If the throttle valve broke, and you could not stop the engine with the throttle, how would you stop it?

A. Lift the eccentric rod off the rocker arm-pin, and move the valve by hand with a starting bar until the valve covers both ports equally, then the engine will come to a stop.

Q. What is meant by a cushion in an engine cylinder?

A.   Cushion is the resistance on the opposite side of piston-head, formed by the steam being shut up in the cylinder, as the piston is nearing either dead center.

Q.   What is meant by clearance?

A.   Clearance is the space between the piston head, cylinder head and valve face at each end of the stroke.

Q.   How would you know the amount of clearance there was in that space?

A.   By finding the number of cubic inches in a bucket of water, then fill up the space level with the steam port, and see how much water is left in the bucket; the difference is the contents in cubic inches.

Q.   Why are gibs, keys and set screws used on both ends of connecting rod?

A.   They are there to take up lost motion.

Q.   How would you do that?

A.   By loosening up the set screw, and driving down the key; then tighten the set screw to keep the key from raising.

Q.   Is there more square inches in one end of the cylinder than the other?

A.   In one sense of the word there are,

and in the other there are not, as the piston rod takes up some of the space in one end of the cylinder, therefore there is not the same area in one end as in the other.

Q. What is a governor on an engine for?

A. It is to regulate the steam that passes from the boiler to the steam chest, when the throttle is wide open.

Q. How does it work?

A. It is regulated to allow the engine to run at a certain speed. The governor has a belt from the main shaft to a pulley on the governor. After the engine is running up to the speed it is intended to, it allows only enough steam to enter through the governor valve to keep the same speed; if the engine needs more power it begins to slack up, the governor balls drop, the valve opens and allows more steam to enter; consequently, the engine must retain her speed; and if the load is taken off it will start to run away, the governor balls will rise, force the valve shut, and cut off the steam; consequently, the engine must come back to its regular speed.

Q. How does a governor valve look?

A. It is a round valve with grooves; there are different kinds, some have three or four openings, and some only two; the more openings the more sensitive the governor.

Q. What is a lubricator for?

A. It is to saturate the steam that passes through the governor valve and the engine valve with oil, so they will not cut. The piston packing rings and the cylinder are also oiled by the same oil.

LINING AN ENGINE.

Q. How would you line up an engine?

A. By stripping the engine, take off both cylinder heads, if convenient ; .then take out the follower-head, piston-rings, bull-ring ; disconnect the piston from cross-head ; also disconnect the connecting-rod from the cross-head and crank-pin ; then take a slotted stick and place it on one of the studs on the end of cylinder furthest from the crank ; then draw a fine sea-grass line over the point of stick and through the center of cylinder, and attach it to a stick at the other end of the bed-plate, nailed to the floor or clamped to the bed-plate ; then take a thin stick, the length of it being a half inch less than half the diameter of cylinder, and stick a pin in each end of the stick, so they can be forced in or drawn out to suit the adjustment ; then center the line at each end of the cylinder at the counter-bore from four sides. Never center the

line in the stuffing box where the piston passes through, but use the inside counter-bore under all circumstances, whether you can remove the back cylinder head or not. Some engine cylinder heads and frames are one ; consequently, the head can not and must not be moved.

Q. If one counter-bore would be out, or larger than the other, what would you do ? Would it not throw the bore of the cylinder or the line out ?

A. No ; center it accordingly ; it would not make any difference, only two centering sticks with pins are needed to bring the line central with the bore.

Q. Why do you use the counter-bore ?

A. Because the counter-bore is the only true bore the cylinder has that is not worn ; consequently, all engineers and machinists must go by it.

Q. What is a counter-bore ?

A. A counter-bore is each end of the cylinder bored from $\frac{1}{16}$ to $\frac{1}{4}$ of an inch larger, from 1 to 4 inches long, according to the size and length of the cylinder.

Q. What is a counter-bore for?

A. To keep the piston from wearing a shoulder in the cylinder at each end.

Q. Why is it that the piston does not wear a shoulder in the cylinder?

A. Because the piston rings just pass over the edge of the regular bore, and by so doing no shoulder can be formed in the cylinder.

Q. How is a cylinder bored?

A. They are generally bored on a regular cylinder boring lathe, which has a table that can be raised or lowered to suit. The regular bore is first bored, then the counter-bore, then the two faces for the heads.

Q. How do you square a shaft when you have got the line centrally through the cylinder?

A. Move the crank-pin down to the line and see where the line touches the crank-pin between the two shoulders, then move the pin over to the other dead center, and see how it comes; if equal, the shaft is square.

Q. If you found it out of square $\frac{1}{2}$ inch, what would you do?

A.   Move the tail-block.

Q.   Why not move the head-block?

A.   Because it would alter the length of the connecting-rod, and be liable to knock out a cylinder-head.

Q.   How would you level a shaft?

A.   A shaft is leveled by a spirit level, or a plumb-line dropped past close to the line that comes through the cylinder directly in front of the center of shaft; let it drop in a bucket of water to keep the plumb-bob from swaying around; then try the crank-pin at both half-strokes (the same principle as in squaring), top and bottom, and see how the crank-pin feels the line; if equal, the shaft is level.

Q.   Is there no other way to level a shaft?

A.   Yes, by the pulley wheel.

Q.   How is it done?

A.   Drop a plumb line down from the ceiling, past the rim's edge of the wheel, directly over the center of the shaft; let the space between the plumb line and rim be one inch; mark the wheel with chalk for a starting and stopping point, and caliper the dis-

tance with inside calipers; then turn the wheel and shaft around, and continue calipering until the wheel has made a full revolution; if it calipers the same all the way around, the shaft is level. This principle answers for trueing a wheel as well as leveling a shaft. The former way, by dropping a plumb line in front of the crank face and feeling the line with the crank-pin at both half-strokes, is the proper way to level a shaft.

Q. If you found the shaft out of level, what would you do?

A. I would have to thin or thicken the brasses, or babbitt the main pillow and tail-block bearings, whichever the case may be.

Q. How would you know if the center of the shaft is in line with the line through the cylinder or not?

A. It can be found out by placing a two-foot steel square against the crank face, under the line through the cylinder, so that the heel of the square is at the center of the shaft, and see how the square touches the line; if it touches exactly, the shaft is in line; if too

hard, the shaft is too high ; if not at all, the shaft is too low.

Q.   How would you raise your shaft ?

A.   There are various ways ; by liners, babbitt, heavier or lighter brasses.

Q.   If your crank face was oval, and you put a square against it, would that be right ?

A.   A spirit level could be placed on a square and bring it level, or drop a plumb-line, and put the end of the square against the crank-shaft center, and let it come against the plumb line.   This is a very true way.

Q.   Now, after your shaft is in line, square and level, and you still find it out over line $\frac{1}{4}$ inch, what would you do ?

A.   I would take it off the crank-pin brasses and fill in the other side with a brass ring, or babbitt the side edge of brasses ; in some cases the side of the connecting rod has to be chipped to allow it to pass free of the crank-face.

Q.   Why would you not take it off the wrist-pin brasses in the cross-head ?

A.   Because the rod would then be out of the center of cross-head, and would have a

tendency to bind the piston in the cylinder
and the cross-heads in the guides, consequent-
ly cutting both.

Q. Would it not make a difference on the
other end of the rod?

A. No, the closer the crank-face the bet-
ter.

Q. Now what would you do?

A. Level and line the guides by putting
them in their place, and line them with a pair
of calipers, by calipering them at both ends
to get them in line with the line through the
cylinder, after having found the distance be-
tween the side of the cross-head and the cen-
ter of the cross-head where the piston enters
the cross-head. Level by spirit level, first
taking spirit level and trying it in the cylin-
der, if a new one, or on top of the cylinder
where it has been planed off when first bored,
for they are the only things to go by.

Q. Would you use the valve seat to level by?

A. No, but alongside of it, where the
steam-chest rests on.

Q. If you had no spirit level, how would
you do it?

A.   With a plumb-line, by placing a square lengthwise on the guides, and try them by bringing the square against the line.

Q.   If you had no two-foot square, and could not get any, how would you lay one off?

A.   Take a pair of dividers, draw a circle, then find four points on the circle, scribe lines from point to point, which gives a square. This should be done very accurately.

Q.   Can a plumb-line hang out of true?

A.   It can not, providing it hangs clear of everything.   If none of these were handy, a straight edge must be placed across the guides at one end, and see if the guides touch the straight edge equally at both edges, then caliper the distance between the line and the straight edge, also at the other end of the guides ; if the same, the guides are level lengthwise with the cylinder and line ; then level the guides crosswise with a plumb-line and square.

Q.   How would you measure your connecting rod?

A.   By finding the striking points.

Q.   How would you do that?

A.   By shoving the piston and cross-head up against the cylinder-head, and making a mark on the guides at one end of the cross-head with a scriber and center-punch; then move the piston and cross-head back to the other cylinder-head and make another mark on the guide at the same end of the cross-head; then measure from the center of crank-pin to center of shaft; that gives the half-stroke; double this, gives full stroke. If half-stroke is 12 inches, the full stroke is 24 inches; then if the distance between the two striking points is 25 inches, and the stroke 24 inches, the clearance between the cylinder-head and piston-head will be $\frac{1}{2}$ inch when the piston is at either end of the cylinder. Then move the cross-head $\frac{1}{2}$ inch back from the striking point, and bring the crank-pin toward the same dead center, ; then take a tram and measure from the outside center of crank-pin to the outside center of wrist-pin in cross-head, which will give proper length of connecting-rod, also the right division of clearance.

Q.   What is meant by clearance in the cylinder?

A.   It is the unoccupied space between the piston-head, cylinder-head and valve-face, when the crank-pin is at either dead center.

Q.   Does the amount of clearance affect the engine's economy?

A.   Yes, it does.

Q.   How much clearance should there be between the piston and cylinder-head?

A.   It depends upon the size; some have from $\frac{1}{4}$ to $\frac{7}{8}$ of an inch.

Q.   What is formed in that space or clearance when running?

A.   A cushion.

Q.   What is a cushion?

A.   A cushion means the steam that enters the cylinder through the lead the valve has, and the resistance it makes on the piston-head, cylinder-head and valve-face, as the engine is reaching the dead-center.

Q.   What is a cushion for?

A.   It is to catch the piston and weight of the machinery as it reaches the dead center, and the lead is to give the engine power at the beginning of the stroke.

Q.   How does it act?

A. The same as a spring on the end of a hammer.

Q. If you wished to shorten or lengthen the connecting-rod, how could it be done?

A. By placing tin or sheet iron liners between the brasses and stub-ends of the connecting-rod.

Q. Now, if the key had to be raised, how could this be done?

A. By putting liners between the straps and brasses.

Q. Would that not alter the length of the rod?

A. No.

Q. With what instrument would you measure a connecting-rod?

A. It is called a "tram."

Q. With what is an engine packed in the stuffing-box?

A. Some engineers use hemp, others use black lead packing, and others use lead rings; there are several kinds. Every engineer to his own taste.

VALVE MOTION.

Q. What is an eccentric?

A. An eccentric is a subterfuge for a crank ; it is something out of center.

Q. How would you find the throw or stroke of an eccentric?

A. By measuring the heavy and the light side ; the difference between the two is the stroke or throw.

Q. What throw should a common slide valve engine eccentric have?

A. Generally double the width of the entry or steam ports.

Q. What is a cam?

A. A cam has no definite meaning ; it has 1, 2, 3 or 4 motions ; they are used on poppet valve engines, such as are in use on high pressure river steamboats.

Q. How would you measure your valve and eccentric rods?

A. By placing the crank-pin at its dead-

center, the center of the eccentric straight or plumb above the center of the shaft, the rocker-arm perpendicular, and the valve covering both ports equally; then take a tram and measure from the center of the eccentric to the center of the pin where the eccentric rod hooks on (generally the lower pin) for the eccentric rod, and from the outside center of the pin where the valve-rod is attached to the furthermost end of the valve, allowing for two nuts at each end of the valve, called adjusting and jamb nuts.

Q. How would you know the eccentric was plumb?

A. By dropping two plumb lines, one at each side of the shaft, and half the space between the two lines will be where the center of the eccentric should stand, with the heavy side up.

Q. What kind of a tool would you use to find the exact center?

A. A pair of hermaphrodite calipers, one leg of which has a sharp point and the other leg has a short foot, so as to feel the line.

Q. What does an eccentric rod consist of?

A.   An eccentric rod consists of a strap, yoke, rod and two nuts; when taking the measure, couple the yoke and strap together, then put a half-inch thick piece of wood between the two straps and find the center of the circle from four sides, with a pair of her maphrodite calipers, then put the rod in the yoke and adjust it to the proper length by the two nuts; if that will not do, the rod must be shortened or lengthened, by cutting out or adding a piece, whichever the case may be. Then take the measure with a tram from the center of the straps to the center of the rod where the rod hooks on the lower rocker-arm pin.

Q.   How long is the thread on a valve-rod?

A.   Long enough to allow two nuts at each end of the valve, and some space for adjustment.

Q.   Now, if your rocker-arm stood at a quarter, and your eccentric out of plumb, how would you take the measure for the rods?

A.   Simply bring them plumb and take the measure; that is the only right way.

Q.　After you have measured your rods, what would you do?

A.　They should be put on and the valve set.

Q.　What do you move or do first, to set a valve?

A.　Move the eccentric in the direction the engine is to run, until the valve begins to take steam or lead, then tighten the eccentric temporarily with set screws, then move the crank pin over to the other dead center, and see how much lead it has; if equal, the valve is set.

Q.　What is meant by the lead of valve?

A.　The opening the valve has when the piston is at the beginning of its stroke.

Q.　What lead should large engines have?

A.　About $\frac{1}{16}$ of an inch. High speed engines must have a quick opening or good lead.

Q.　Now, if you find the valve laps out $\frac{3}{8}$ of an inch on one end, and the proper lead on the other, what would you do?

A.　Divide the difference, by moving the valve one-half it is out, by adjusting the nuts on the valve gear.

Q.   How much?

A.   The valve has $\frac{1}{16}$ of an inch lead at one end and laps $\frac{3}{8}$ of an inch at the other end; the valve is out $\frac{7}{16}$ of an inch; then the valve must be adjusted by the nuts one-half it is out, making $\frac{7}{32}$ of an inch.   Then throw the crank on the other dead center, move the eccentric whichever way will bring you back to $\frac{1}{16}$ of an inch lead, then tighten temporarily with set screws, throw crank over on the other dead center, and the valve will be set. After the valve is set, tighten the eccentric for good.

Q.   But if it is not set, what then?

A.   Go through the same performance until it is set.   Some valve-rods have a yoke that slips over the valve, while the adjusting and jam-nuts are between the stuffing box and the rocker-arm pin.   When a valve-rod has no nuts, the adjusting must be done at the eccentric rod.   To lengthen or shorten the stroke of valve-rod, raise or lower the eccentric-rod pin in the slot, at the bottom of the rocker-arm, whichever way suits the circumstances.

Q   Now, after you have set your valve,

keyed everything up properly, and there was a thud or dead sound in the engine or cylinder, what would you do, or where would you look for the trouble ?

A. In the exhaust being choked. The steam-chest cover must be taken off, then uncouple the valve, turn the valve up sideways and move it until the steam edge has the proper lead with the steam-port, then place a square on the valve-seat of the cylinder, and against the valve-face, to see how the exhaust lead on the opposite steam port corresponds ; if it is choked, then scribe it by allowing a little over double the steam lead.

Q. How would you make the exhaust larger ?

A. By chipping it out of the exhaust cavity in the valve, and rubbing a file over it to smooth it.

Q. Do you think a little over double the steam-lead would be sufficient ?

A. Yes ; if not, take out a little more.

Q. Where should the exhaust be ?

A. It should be the furthest from the steam-port that is receiving.

Q. What would you do in case your eccentric slipped?

A. Set the valve the same as before.

Q. Is the principle of valve setting the same?

A. Yes; some engines have two steam and two exhaust valves, but that makes no difference, the principle is the same.

Q. How would you find the dead center of an engine?

A. By placing a spirit level on the strap that goes around the brasses that connect the crank-pin to the connecting-rod, and when it is level the crank is at dead center. If the engine is not level, then an adjustable level must be used.

Q. What other way could you find the dead center of an engine?

A. By moving the engine toward the dead center until the cross-head stopped moving; then put a center punch mark in the floor, and one on the fly-wheel, after having marked it with a tram; then move the crank over the center until the cross-heads begin to move, then put another mark; the middle between

the two marks is the exact dead center ; then bring the middle mark to the point of the tram ; this is done with a small tram with one straight point and a short foot.

Q. If the engine had to be run in the opposite direction to which it had been running, how could it be done?

A. It could be done by placing the crank-pin on the dead center, removing the steam-chest cover, and turning the eccentric over on the shaft in the opposite direction, until the valve has the proper lead at the opposite port, then try the engine from dead center to dead center, to equalize the lead at both ends of the valve ; then the engine will run in the opposite direction.

Q. Does a crank-pin and piston travel the same distance?

A. No, a crank-pin travels $1\frac{1416}{10000}$ times further than the piston each revolution, or $0.\frac{5707}{10000}$ times further each stroke. For example, take an engine with a 12-inch stroke, the piston travels 24 inches and the crank-pin $37\frac{6992}{10000}$ inches each revolution, or the piston travels 12 inches each stroke and the crank-pin

13.6992 per single stroke of piston. To do this, multiply the single stroke by 3.1416 and subtract the double stroke from the answer; the remainder will be the distance the crank-pin travels further than the piston. This rule answers for all engines. Another fact not generally known by many men is that a crank of an engine, at two certain points, travels a long distance while the motion of the cross-head is hardly noticed.

When the center of the crank-shaft and crank-pin are in line with the piston-rod, no steam pressure applied to either side of the piston can set the engine in motion; this is called the dead center.

Q. What is a revolution?

A. It means the crank has turned once around, or made a circle.

Q. How many strokes has a revolution?

A. Two.

EXAMPLE: If an engine has 24 inches stroke, and makes 65 revolutions per minute, how many feet does it travel in a minute? 24 inches multiplied by 2 equals 48 inches, this multiplied by 65 revolutions equals 3120

inches, which divided by 12 equals 260 feet per minute.

Q. If you were asked the horse power of any sized engine, could you tell it?

A. Yes.

Q. Well, how would you go about it, and what is a horse power?

A. A horse power is 33,000 pounds raised 1 foot high in 1 minute, or 150 pounds raised 220 feet high in 1 minute. To find the horse power of any engine, first find the area of the piston-head face, then multiply the answer by the average pounds pressure per square inch, then multiply by the number of feet traveled in 1 minute, and divide by 33,000.

EXAMPLE:

Cylinder 12 x 24 in.	12	diam. of cylinder.
65 revolutions,	12	
Average pressure 80 ℔s.	144	sq. of diameter.
	.7854	

113.0976 area of p. h. face.
80 average pressure.

9047.8080
260 No. ft. trav. by p.

33000)2352430.0800(71.2857 horse pow.

THE INDICATOR.

The steam engine indicator is an instrument for showing the pressure of steam in the cylinder at all points of the stroke, or for producing actual diagrams. The indicator consists of a small cylinder accurately bored out, and fitted with a piston, capable of working in the (indicator) cylinder with little or no friction, and yet be practically steam-tight. The piston has an area of just $\frac{1}{2}$ of a square inch, and its motion in the cylinder is $\frac{25}{32}$ of an inch.

The piston-rod is connected to a pair of light levers, so linked together that a pencil carried at the center of the link moves in nearly a straight line through a maximum distance of $3\frac{1}{8}$ inches. A spiral spring placed in the cylinder above the piston, and of a strength proportioned to the steam pressure, resists the motion of the piston ; and the elasticity of this spring is such that each pound of pressure on the piston causes the pencil to

move a certain fractional part of an inch. The pencil in this case is made of a piece of pointed brass wire, which retains its sharpness for a considerable time, and yet makes a well-defined line upon the prepared paper generally used with the indicator.

The paper is wound around the drum, which has a diameter of 2 inches, and is capable of a semi-rotary motion upon its axis to such an extent that the extreme length of diagram may be $5\frac{1}{4}$ inches. Motion is given to the drum in one direction, during the forward stroke of the engine, by means of a cord connected indirectly to the cross-head of the engine, and the drum is brought back again during the return stroke of the engine by the action of a coiled spring at its base.

The conical stem of the instrument permits it to be turned around and fixed in any desired position, and the guide-pulleys attached to the instrument under the paper drum may also be moved around so as to bring the cord upon the drum-pulley from any convenient direction.

The upper side of the piston is open to the

atmosphere; the lower side may, by means of a stop-cock, be put into communication either with the atmosphere or with the engine cylinder.

When both sides of the piston are pressed upon by the atmosphere, the pencil, on being brought into contact with the moving paper, describes the atmospheric line. When the lower side of the piston is in communication with the engine cylinder, the position of the pencil is determined by the pressure of the steam existing in the cylinder; and on the pencil being pressed against the paper during a complete double stroke of the engine, the entire indicator diagram is described.

In order that the diagram shall be correct, the motion of the drum and paper shall coincide exactly with that of the engine piston; second, that the position of the pencil shall precisely indicate the pressure of steam in the cylinder; third, that the pendulum must be from $1\frac{1}{2}$ to 3 times as long as the stroke of the engine piston; fourth, that the pendulum must be plumb when the piston is at half-stroke; fifth, that the cord around the drum

must be attached to the pendulum at right angles, or square with the indicator; sixth, the pendulum must be attached with an inch wooden pin to the ceiling or floor at one end, the other end to the cross-head by means of a screw-bolt in the wrist-pin and a slot in the pendulum; seventh, that the two holes tapped in the cylinder are directly opposite the steam ports, and centrally between the piston-head and cylinder head, when the engine is at the dead center, or, in other words, in the center of clearance; eighth, that the piping should be as short as possible, and $\frac{1}{2}$ inch pipe if not over 1 foot long. If longer the pipe should be larger close to the cylinder, and covered so as not to allow too much condensation, as it affects the diagram. The best way to take a diagram is to tap a hole in each cylinder-head and take each end separately. The cord must be attached to the pendulum, so the paper drum will move in proportion to the piston.

An indicator shows the highest and the lowest pressure reached, also the cut-off and lead. If there is a great difference, say more than 5 pounds, between the boiler pressure

and the initial pressure upon the piston, the connecting pipes may be taken as being too small, too abrupt, or the steam ports too contracted. The full pressure of steam should come upon the piston at the very beginning of its stroke. Should the admission corner be rounded, the valve is wanting in "lead," or, in other words, the port for the admission of steam is uncovered too late in the stroke.

The steam line should be parallel or straight with the atmospheric line up to the point of cut-off, or nearly so. Should it (the steam line) fall as the piston advances, the opening for the admission of steam is insufficient, and the steam is "wire-drawn."

The point of cut-off should be sharp and well defined; should it be otherwise, the valve does not close quick enough. The bevel line leading from the cut-off line to the end of the stroke is called the expansion line.

Q. What is the standard indicator?

A. The Tabor's improved.

Q. Are there any other makes?

A. Yes; Richard's, McNought's, Thompson's and others.

RULES.

RULE for telling the power of a diagram :
Set down the length of the spaces formed by
the vertical lines from the base in measure-
ments of a scale accompanying the indicator,
and on which a tenth of an inch usually rep-
resents a pound of pressure ; add up the total
length of all the spaces, which will give the
main length, or the mean pressure upon the
piston in pounds per square inch ; to do this,
lay a card taken by the indicator off in ten
parts, by drawing lines from top to bottom.
Find out what the scale is ; suppose it is 60,
the number of ordinates 10, and that the sum
of their length is 6 inches ; so 6 and 10
ordinates $= \frac{6}{10}$ or .6 x 60 $=$ 36.0. Answer,
36 pounds pressure upon the piston.

RULE for finding and deducting friction :
Multiply N. H. P. by .13 and subtract the
answer from N. H. P., which gives I. H. P.

Q. What is N. H. P. ?

A. It is nominal horse power.

Q. What is I. H. P. ?

A. It is indicated horse power.

Q. What is meant by cutting off steam at 6 inches?

A. It means that the valve closes and cuts off the live steam from the boiler at 6 inches of the piston's travel ; then the engine gets its power, from the time the valve closes or cuts off until the exhaust opens, by the expansion of the steam closed up in the cylinder.

Standard multipliers, with examples :

1.	For the Area of a Circle,	Multiply sq. of diam. by .7854
2.	For Circumference of a Circle,	Multiply diameter by 3.1416
3.	For Diameter of a Circle,	Multiply circum. by .31831
4.	For the Surface of a Ball,	Multiply sq. of diam. by 3.1416
5.	For the Cubic Inches in a Ball,	Multiply Cube of di. by .5236

1. RULE for finding the area of any circle. Always multiply the diameter by itself, then by .7854, then cut off 4 decimals to the right.

2. RULE for finding the circumference of anything round. Multiply the diameter by 3.1416, and cut off 4 decimals.

3. RULE to find the diameter of a circle. Multiply circumference by .31831.

EXAMPLE: The circumference 9.4248 x .31831 = 3.000008088 = 3 inches diameter.

4.   RULE to find the surface of a sphere, globe or ball.

EXAMPLE: 9 inches diameter x 9 = 81 x 3.1416 = 254.4696.

5.   RULE to find the cubic inches in a ball. Multiply cube of the diameter by .5236 ; the answer equals its solid contents.

EXAMPLE: Ball 3 inches in diameter; 3 x 3 = 9; 9 x 3 = 27 x .5236 = $14\frac{1372}{10000}$ solid contents.

RULE to find the pressure on the crown sheet of a hanging fire-box boiler.   Multiply the width by the length in inches, then multiply by steam gauge pressure and divide by 2.

EXAMPLE:

Crown sheet 46 x 33 in.	46
Pressure 85 ℔s.	33
Iron ½ in.	1518
	85
If iron is ¼ in. div. by 4.	2)129030
If iron is ⅝ in. div. by 2.66	2000)64515 ℔s. press'e.
	32.$\frac{257}{}$ tons "

RULE to find how much water a boiler will contain.   For 2-flue boiler, ⅔ full of water, find ⅔ of the area of the boiler in inches inside ; multiply by length in inches ; then find

area of flues, thickness of iron added; then multiply by 2, if 2 flues; multiply by length in inches, subtract area of flues from $\frac{2}{3}$ contents, and divide by 231 (number of cubic inches in a standard gallon); the answer will be the number of U. S. standard gallons.

EXAMPLE:

Boiler 48 inches.	48
Two flues, 16 in. each.	48
Length 20 feet.	2304
16	.7854
16	3)1809.5616 Area of Boiler.
256	603.1872 One-third of Area.
.7854	2
201.0624	1206.3744 Two-thirds of area
2	240 Length in inches.
402.1248	289529.8560
240	96509 9520 Sub. Area of Flues.
96509.9520	231)193019.9040
	835.5840 No. of Gallons.

RULE to find the amount of water required, when the average pounds of coal used per hour is known. Divide the coal by 7.5; the answer will be cubic feet; then multiply by 7.5, and that gives the number of U. S. standard gallons.

EXAMPLE:

117 ℔s. of coal used per hour,   7.5)117.0

$$\frac{15}{7.5}$$

112.5 = 112½ gals.

Q. How many cubic feet in 1 ℔. of air?

A. $13\frac{817}{1000}$ cubic feet.

Q. How much air does it take to consume 1 pound of coal?

A. It takes 18 pounds, or $248\frac{706}{1000}$ cubic feet.

Q. How would you tell the amount of water any tank contained?

A. If the tank was large at the bottom and narrow at the top, lay the tank off in 10 parts from top to bottom, then take the diameter $\frac{4}{10}$ from the large end of the tank, square it, then multiply by .7854; that gives the area; then multiply quotient by full depth of tank and divide by 1728, which gives the number of cubic feet; multiply answer by 7.5, and the number of U. S. gallons will be given. The example must be done in inches; 1728 is the number of inches in a cubic foot, and 7.5 is the number of gallons in a cubic foot.

EXAMPLE:

Tank 2 feet diam.   24 inches diameter.
Tank 3 feet deep.   24 "   "

$$\begin{array}{r} 24 \\ 24 \\ \hline 576 \\ .7854 \\ \hline 452.3904 \text{ area in inches.} \\ 36 \text{ inches deep.} \\ \hline 1728)16286.0544 \\ \hline 9.4248 \text{ cubic feet.} \\ 7.5 \text{ No. gals. in cub. ft.} \\ \hline 70.68600 \text{ U. S. gals. in tank.} \end{array}$$

RULE how to mark engineer's tools. Warm the tool and allow a thin coat of beeswax to cover the place to be marked; after the beeswax is cold, take a dull scriber and do the marking; then apply some nitric acid, after a few moments wash off the acid with water, then heat the tool to melt the beeswax, and you will find well defined marks.

RULE for chimneys. Chimneys should be round inside, instead of square, to insure a good draft. The opening should be one-fifth larger than the area of the flues or tubes combined; if less, the draft will not be free. The opening from the bottom should increase in size to the top, and be as smooth as possible inside.

RULE for making good babbitt metal, for high and low speed, in parts.

HIGH SPEED.		COMMON.		MEDIUM.	
Martin's Nickel...	10	Copper	12	Copper	60
Copper	16	Antimony.... ...	4	Antimony	25
Antimony.........	4	Tin...............	84	Tin...............	15
Tin...	70				
	100		100		100

RULE for babbitting a box. Nearly every engineer has his own way ; but the best and quickest way is to chip out all the old babbitt in the cap and box, then put the journal or shaft that is to run in the box in its place ; put enough liners in between the shaft or journal and edge of box until level, square and in line ; put thick putty around the shaft and against the box, so the babbitt can not run out ; then heat the babbitt until it runs free, and pour accordingly ; the cap is then bolted in its place upon $\frac{1}{16}$ inch thick liner, and putty placed as before ; then pour the metal through the oil holes, which will have to be drilled out afterwards.

RULE to determine the capacity of any size pump, single or double action. Multiply the area of the water piston-head face or

plunger in inches, by its stroke in inches, which gives the number of cubic inches per single stroke; the answer divided by 231 (the cubic inches in a gallon) will give the number of standard gallons per single stroke. But remember, all pumps throw less water than their capacity, which depends upon the condition and quality of the pump. This loss arises from the rise and fall of the valves; from a bad fit or leakage, and in some cases from there being too much space between the valves, piston or plunger. The higher the valves have to rise to give the proper opening, the less work the pump will perform.

Q. Will a boiler 60 inches in diameter, ⅜ inch iron, stand as much pressure as a boiler 48 inch diameter, ⅜ inch iron?

A. No.

Q. Why?

A. Because the pressure in the large boiler has more surface, and will not allow it. It is the same as a long bar and a short bar of the same thickness; it takes less strain to break the long one than the short one.

Rule for finding safe working pressure of steam boilers. Always use .56 for single riveted and .70 for double riveted side seams. A radius means one-half the diameter; and one-fifth of the tensile strength is the safe load. U. S. standard is one-sixth.

Multiply the thickness of iron by single or double rivets, then multiply by the safe load, divide by internal radius, and the answer will be the safe working pressure.

EXAMPLE:

Diam. 42 in.   .1875 thickness of iron.
Iron $\frac{3}{16}$ in.   .70 double riveted.

Double riveted and .131250
50,000 lbs. tensile str'th. 10000 2)42

          20.8125)13125000.00   21 outside radius.

  Safe working pressure. 63.06   .1875

                  5   20.8125 inside rad.

  Bursting pressure.   315.30

Rule to find aggregate strain caused by the pressure of steam on the shells of boilers. Multiply the circumference in inches by the length in inches; multiply this answer by the pressure in pounds. The result will be the pressure on the shell of boiler, and divide by 2000, which gives the tons.

EXAMPLE:

Diam. of boiler 48 inches, circumference 150.7968, length 20 feet, or 240 inches, pressure of steam 120 lbs. 150.7968 x 240 x 120 = 4342947.8400 lbs., divided by 2000 = 2171½ tons strain.

RULE to find the number of feet of 1 inch pipe required to heat any size room with steam. For direct radiation 1 lineal foot (straight foot) to 25 cubic feet of space. For indirect radiation, 1 lineal foot to 15 cubic feet of space. Note, all pipe is measured inside for size.

EXAMPLE:

Room 18 x 18 x 18 to be heated with 1 inch pipe. Direct radiation. All calculating must be done in inches, and divided by 1728 to give the cubic feet.

$$\begin{array}{r} 216 \\ 216 \\ \hline 46656 \\ 216 \\ \hline \end{array}$$

1728)10077696 cubic inches.

25)5832 cubic feet.

Lineal   233$\frac{7}{25}$ feet of 1 inch pipe.

One cubic foot of boiler is required for every 1500 cubic feet of space to be warmed. One horse-power of boiler is enough for 40,000 cubic feet of space.

RULE to find the horse power of a boiler. Always find the number of square inches and divide by 144, which gives the square feet of heating surface, and divide by 15 square feet, which is an average allowance for one horse power of a boiler; divide the H. P. by 2, you will have the proper grate surface, and allow $\frac{1}{2}$ square inch of safety valve to each square foot of grate surface. Generally, from $\frac{1}{2}$ to $\frac{3}{4}$ of a square foot of grate surface is allowed to each horse power of a boiler.

Q. How do you find the horse power of a boiler?

A. Find the number of square feet of heating surface and divide by 15; 15 square feet of heating surface is the general allowance for a H. P. of a boiler. (See following example.)

EXAMPLE:

Boiler 48 in. x 25 ft.   First find circum. of boiler.

Two 16 in. flues.   16   diam. of 1 flue.

   48 diam. of shell.   3.1416

   3.1416   50.2656 circ. of 1 flue.

3)150.7968   300 length of flue

   50.2656 one-third circum. 15079.6800 in inches.
        2   2

  100.5312 two-thirds " 30159.3600 heat. sur. 2 fl.
     300 length or boiler in inches.

30159.3600 No. sq. in. heat. surf. 16 in diam. of 1 flue.
          in the shell.   16

   48   256
   48   .7854

 2304   201.0624 area 1 flue.
  .7854   2

3)1809.5616 area of 1 head.   402.1248 area 2 flues.

  603.1872 one-third area of 1 hd.   2
     2   804.2496 both ends.

 1206.3744 two-thirds area of 1 hd.
    2

 2412.7488 two-thirds area both hds.
No. sq. in. heat. surf. in shell, 30159.3600
  "   "   " flues, 30159.3600
Two-thirds area both heads,   2412.7488

  Total,   62731.4688
Subtract area of flues,   804.2496
  This boiler is 28 h. p. An 144)61927.2192

engine uses about ⅓ of boil- 15)430.   sq. ft. h. s.

er's h. p., making this boil-   2)28.   h. p.

er sufficiently large enough   2)14.   grate surf.

to supply engine of 84 h. p.   7.   area s'fty v.

RULE to find the horse power generated in any kind of boiler when running. First, notice how long it will take to evaporate 1 inch of water in the glass gauge, divide this into 60, which gives the number of inches evaporated in one hour; second, multiply the average diameter where evaporation took place by the length of the boiler in inches; this multiplied by the number of inches evaporated, and the answer divided by 1728 gives the cubic feet of water evaporated in one hour.

As a rule, 1 cubic foot of water evaporated is generally allowed for 1 horse power; also the capacity of a pump or injector for any boiler should deliver 1 cubic foot of water each horse power per hour, and an engine uses one-third of a cubic foot of water per horse power.

<div align="center">EXAMPLE:</div>

Length of boiler 216 inches.		216
Average diam. 40 inches.		40
One inch evaporated in	15)60	8640
15 minutes.	4	4
		1728)34560
		20 horse pow er

WEIGHT OF SQUARE SUPERFICIAL FOOT OF BOILER PLATE WHEN THICKNESS IS KNOWN.

Thickness.	Weight.	Thickness.	Weight.
Inches. Dec.	lbs.	Inches. Dec.	lbs.
$\frac{1}{32}$ = .03125	1.25	$\frac{5}{16}$ = .3125	12.58
$\frac{1}{16}$ = .0625	2.519	$\frac{3}{8}$ = .375	15.10
$\frac{3}{32}$ = .0937	3.788	$\frac{7}{16}$ = .4375	17.65
$\frac{1}{8}$ = .125	5.054	$\frac{1}{2}$ = .5	20.20
$\frac{5}{32}$ = .1562	6.305	$\frac{9}{16}$ = .5625	22.76
$\frac{3}{16}$ = .1875	7.578	$\frac{5}{8}$ = .625	25.16
$\frac{7}{32}$ = .2187	8.19	$\frac{3}{4}$ = .75	30.20
$\frac{1}{4}$ = .25	10.09	$\frac{7}{8}$ = .875	35.30
$\frac{9}{32}$ = 2812	11.38	1 = 1	40.40

Q. Explain how the above fractional parts of whole numbers are made to read as decimals—take $\frac{3}{16}$ of an inch for an example?

A. To do this, take 100 as a whole number; 16 into 100 is .625 x 3 = .1875. This principle answers for all the rest.

RULE for safety valves. To find the distance ball should be placed on lever, when the weight is known, or the distance is known and weight is not known. Multiply the pressure required by area of valve, multiply the answer by the fulcrum; subtract the weight of the lever, valve and stem, and di-

vide by the weight of ball for distance, or divide by distance for the weight of ball with the same example as follows:

<div align="center">EXAMPLE:</div>

Weight of ball,	60 lbs.	100 lbs. pressure.
Pressure,	100 "	3 area of valve.
Wt. of L. V. & stem,	30 "	300
Fulcrum,	4 inch.	4 fulcrum.
Area of valve,	3 "	1200
		30 wt. of L. V. & st.
		60)1170
		19½ inch ball should be hung on lever.

The mean effective weight of valve, lever and stem is found by connecting the lever at fulcrum, tie the valve-stem to lever with a string, attach a spring scale to lever immediately over valve, and raise until the valve is clear of its seat, which will give the mean effective weight of lever, valve and stem.

RULE for figuring the safety valve and to know the pressure, when the area of valve, the weight of lever, valve and stem, the distance fulcrum is from valve, and weight of ball is known.

Divide fulcrum into length of lever, multiply answer by weight of ball, add weight of lever, valve and stem, and divide by area of valve. Answer will be steam pressure.

EXAMPLE:

Weight of ball,	50 lbs	2.25	4)20
Wt. of L. V. and stem,	30 lbs	2.25	5
Fulcrum,	4 in.	5.0625	50
Diam. of valve,	2¼ in.	.7854	250
Length of lever,	20 "	3.97608750 area.	30

3·9)280.0

lbs. press. 71.$\frac{31}{39}$

Add as many ciphers to the dividend as there are decimals in the divisor, and divide as whole numbers.

To measure or mark off the lever, you measure the fulcrum and make notches the same distance as fulcrum ; if fulcrum is 4 inches, each notch must be 4 inches apart.

Q.   What is meant by a fulcrum ?

A.   The distance valve stem is from where the lever is connected.

RULES.

───

Rule to Gear a Lathe for Screw Cutting.—Every screw cutting lathe contains a long screw called the lead screw, which feeds the carriage of the lathe while cutting screws ; upon the end of this screw is placed a gear to which is transmitted motion from another gear placed on the end of the spindle ; these gears each contain a different number of teeth, for the purpose of cutting different threads, and the threads are cut a certain number to the inch, varying from 1 to 50. Therefore, to find the proper gears to cut a certain number of threads to the inch, you will first multiply the number of threads you desire to cut to the inch by any small number, 4 for instance, and this will give you the proper gear to put on the lead screw. Then with the same number, 4, multiply the number of threads to the inch in the lead screw, and this will give you the proper gear to put on the spindle. For example, if you want to cut 12 to the inch, multiply 12 by 4, and it will give you 48. Put this gear on the lead screw, then with the same number, 4, multi-

ply the number of threads to the inch in the
lead screw. If it is 5, for instance, it will
give you 20 ; put this on the spindle and
your lathe is geared. If the lead screw is 4,
5, 6, 7 or 8, the same rule holds good. Al-
ways multiply the number of threads to be
cut first. Some—indeed, most small lathes
—are now made with a stud geared into the
spindle, which stud only runs half as fast as
the spindle, and in finding the gears for these
lathes you will first multiply the number of
threads to be cut, as before, and then multi-
ply the number of threads on the lead screw
as double the number it is. For instance, if
you want to cut 10 to the inch, multiply by
4, and you get 40 ; put this on the lead
screw ; then, if your lead screw is 5 to the
inch, you call it 10, and multiply by 4, and
it will give you 40. Again put this on your
stud and your lathe is geared, ready to com-
mence cutting.

RULE FOR CUTTING A SCREW IN AN ENGINE
LATHE.—In cutting V-thread screws, it is only
necessary for you to practice operating the
shipper and slide screw-handle of your lathe
before cutting. After having done this until
you get the motions, you may set the point
of the tool as high as the center, and if you
keep the tool sharp you will find no difficulty

in cutting screws. You must, however, cut very light chips, mere scrapings in finishing, and must take it out of the lathe often, and look at it from both sides very carefully, to see that the threads do not lean like fish scales. After cutting, polish with a stick and some emery and oil.

RULE FOR CUTTING SQUARE THREAD SCREWS.—In cutting square thread-screws, it is always necessary to get the depth required with a tool somewhat thinner than one-half the pitch of the thread. After doing this, make another tool exactly one-half the pitch of the thread, and use it to finish with, cutting a slight chip on each side of the groove. After doing this, polish with a pine stick and some emery. Square threads for strength should be cut one-half the depth of their pitch, while square threads for wear may—and should be—cut three-fourths the depth of their pitch.

RULE FOR MONGREL THREADS.—Mongrel, or half V half square threads, are usually made for great wear, and should be cut the depth of their pitch, and for extraordinary wear they may even be cut $1\frac{1}{2}$ the depth of the pitch. The point and the bottom of the grooves should be in width $\frac{1}{4}$ the depth of their pitch. What is meant here by the

point of the thread is the outside surface; and the bottom of the groove is the groove between the threads. In cutting these threads it is necessary to use a tool about the shape of the thread, and in thickness about one-fifth less than the thread is when finished. As it is impossible to cut the whole surface at once, you will cut it in depth about $\frac{1}{16}$ at a time, then a chip off the sides of the thread, and continue in this way alternately till you have arrived at the depth required. Make a gauge of the size required between the threads and finish by scraping with water. It is usually best to leave such screws as these a little large until after they are cut, and then turn off a light chip, to size them; this leaves them true and nice.

RULE TO TEMPER TOOLS USED DAILY, SUCH AS CHISELS, TAPS, DIES, REAMERS, TWIST DRILLS, COMMON FLAT DRILLS, AND LATHE TOOLS.—To temper flat, cape or side chisels, and common flat drills, put the tool to be tempered in the fire and heat slowly to a cherry red color, about 4 inches from the point. Then take it out and put it in the water, point first, about three or four inches, then draw it back quick about an inch from the point, and leave it so until the water will barely dry on the chisel, then take it out,

polish it with a piece of sand stone, and let the heat that is left in the body of the tool force its way toward the point; it will be noticed immediately in the change of color. The color of temper for chisels to cut cast iron should be a dark straw, turning to a blue. The temper of chisels to cut wrought iron or steel should be plunged into water after the dark straw color has disappeared and the blue begins to show itself, and left in the water to cool off. In some cases, where the tool is too cold and the temper will not draw, put the tool in and out of the fire often, until the temper shows itself, then cool off immediately. If the temper gets to the point of tool before it is polished, it will have to be heated over again. The above rule answers for lathe, plainer and shaper tools as well.

Taps, dies, reamers and twist drills should be tempered in oil. After being heated to a cherry red all over equally, drop the tool into a bucket of oil (plumb) and leave it there until cold; then take it out and brighten it with emery cloth; be careful not to drop it, because it is brittle and liable to break. To draw the temper of taps, reamers and twist drills, heat a heavy ring red hot and enter the tool centrally in the ring, so the heat will be equal from all sides. The hole in the ring

should be about three times the diameter of the tool. An old pulley hub would be about right. The color for reamers, taps and twist drills should be dark straw, turning to blue near the shank; where the color is changing too fast, drop a little water on it; after the right color is obtained, cool off in water. To draw the temper in dies after being cooled in oil, set them (the threads up) on a piece of red-hot iron and draw temper the same color as taps.

For tempering a spring, heat it cherry red and put it in oil; after it is cool, take it out and hold it over the fire until the oil burns off; then put the spring in the oil again, then in the fire; do this three times; after the last time, plunge it into water and cool off.

THE END.

MULTIPLICATION TABLE.

1	x	1	—	1	2	x	1	—	2	3	x	1	—	3
1	x	2	—	2	2	x	2	—	4	3	x	2	—	6
1	x	2	—	3	2	x	3	—	6	3	x	3	—	9
1	x	4	—	4	2	x	4	—	8	3	x	4	—	12
1	x	5	—	5	2	x	5	—	10	3	x	5	—	15
1	x	6	—	6	2	x	6	—	12	3	x	6	—	18
1	x	7	—	7	2	x	7	—	14	3	x	7	—	21
1	x	8	—	8	2	x	8	—	16	3	x	8	—	24
1	x	9	—	9	2	x	9	—	18	3	x	9	—	27
4	x	1	—	4	5	x	1	—	5	6	x	1	—	6
4	x	2	—	8	5	x	2	—	10	6	x	2	—	12
4	x	3	—	12	5	x	3	—	15	6	x	3	—	18
4	x	4	—	16	5	x	4	—	20	6	x	4	—	24
4	x	5	—	20	5	x	5	—	25	6	x	5	—	30
4	x	6	—	24	5	x	6	—	30	6	x	6	—	36
4	x	7	—	28	5	x	7	—	35	6	x	7	—	42
4	x	8	—	32	5	x	8	—	40	6	x	8	—	48
4	x	9	—	36	5	x	9	—	45	6	x	9	—	54
7	x	1	—	7	8	x	1	—	8	9	x	1	—	9
7	x	2	—	14	8	x	2	—	16	9	x	2	—	18
7	x	3	—	21	8	x	3	—	24	9	x	3	—	27
7	x	4	—	28	8	x	4	—	32	9	x	4	—	36
7	x	5	—	35	8	x	5	—	40	9	x	5	—	45
7	x	6	—	42	8	x	6	—	48	9	x	6	—	54
7	x	7	—	49	8	x	7	—	56	9	x	7	—	63
7	x	8	—	56	8	x	8	—	64	9	x	8	—	72
7	x	9	—	63	8	x	9	—	72	9	x	9	—	81

CONTENTS.

Just Published.

Zwicker's Instructor,

—IN—

QUESTIONS AND ANSWERS FOR ENGINEERS,
FIREMEN AND MACHINISTS TO PROCURE
STATIONARY ENGINEERS' LICENSE,
SURE.

Price, ... $2 00

ZWICKER'S INSTRUCTOR,

The only practical work published in the United States giving plain and correct explanations in regard to Engines, Pumps, Boilers, Removing Scale, Valve Motion, Indicator, United States Standard Rules for Safety Valve, etc., how to figure the kind of gears to put on a Lathe for cutting Screws, and the Tempering of Tools used daily.

Price, ... $2 00

These are the only books ever published explaining Steam Engineering plainly and practically, so that Engineers, Machinists and Fremen of limited education can understand and become expert practical engineers.

Either of the above books will be sent to any part of the United States or Canada on receipt of price.

Send money in registered letter or P. O. order, to

P. O. ZWICKER.
1117 Madison St., St. Louis, Mo.